Spring 2019

Custom Foot Prosthetic: Diabetic Care

Chandler Streuli
Central Washington University, chandler.streuli@cwu.edu

Custom Foot Prosthetic: Diabetic Care

By

Chandler Streuli

Table of Contents

Abstract

Across the United States there are people every day who lose their toes to diabetes or to loss of circulation within their legs. The problem becomes building a more cost effective and efficient prosthetic for these individuals. The prosthetics that are used for medical purposes are often costly, especially without the help of insurance. The new prosthetic was designed to be taken in and out of shoes so that it is fast and easy for the user to move the device from shoe to shoe. The manufacturing method for this project was using a 3D printer to build the initial project. The 3D printed material was the most cost effective and would be cheaper than a molding or casting process for the prototype. 3D printing also provides the ability to prototype more than one copy in a short amount of time. The testing involved hardness and impact tests as well as various stress tests. These are used to simulate everyday stress on the prosthetic when someone is walking or running into objects. The results from these tests showed the prosthetic can withstand a 220 pound force stepping onto it. The insert can also withstand an impact force of 20 pounds. Both of these forces fall within the requirements, which were having the device withstand a weight of 200 pounds, withstand a kicking force of 20 pounds, and be under a weight of 2 pounds.

1: INTRODUCTION

1a: Description:

There are a lot of cases across the world of diabetics losing their toes due to their diabetes. The reason being is because the diabetes causes issues with circulation of blood in the body and can sometimes cause blood to not get to certain parts of the body. When this happens, the hospital will often make an insert or give the individual special shoes to help them walk so they do not have to wear a heavy boot all the time. These shoes are often called clunky and uncomfortable and the inserts do not fit into the shoes easily and comfortably.

b. Motivation:

The project was motivated to create a more comfortable and simple design for an insert for patients of toe loss due to diabetes. Hopefully, creating a better quality of life and a more cost-effective solution to toe loss since special shoes and inserts made by the hospitals can be costly.

c. Function Statement.

To create an insert that provides a better quality of life and to fit within a shoe comfortably.

d. Requirements:

The insert will follow the requirements stated below:

- Must weigh between .25-.5lbs
- Can hold a stiffness of 50lbs per inch
- Withstand a kicking force (like stubbing toe) of 15lbs
- Can fit within the standard shoe of individual

e. Success Criteria:

Can withstand the given requirements above and has the ability to be used for more than one application.

f. Scope:

The project will be focused on building a specific insert to the front of the shoe. However, there will be no designing of a pad or custom shoe to fit the insert. The insert itself must fit within a normal shoe given the size of the person being fit to.

g. Benchmark:

The link below shows a product that is like what this project is designed for. However, the product in the URL uses a pad on the bottom that supports the foot too. The product for this project is focused more on just an insert and not a pad like a sole of a shoe. The reason being is because the insert is meant to be a quick slip in process for the user and not require too much replacing of materials in the shoe.

http://www.polarispt.com/pedorthics-toe-fillers.html

h. Success of the project:

The project will be deemed a success if it holds to the requirements stated above and is given a 10% more comfortable aspect to the user compared to other products already out there. This project does not have to be the end all be all option for users, but it should be considered an option above some other options.

2. DESIGN AND ANALYSIS

a. Approach

The design of this project was conceived through a means of helping others with an issue that is common across the United States and across the world. This design was also based around similar designs seen on the internet but tweaked and changed to fit the parameters needed for the initial testing and guidelines.

b. Design Description (picture, sketch, rendering)

Look at appendix B

c. Benchmark

A benchmark for this project would be to emulate something similar to the insert that is used in the link below. The design is different than what the insert for this project will be, but, it was the closest one found.
http://www.polarispt.com/pedorthics-toe-fillers.html

d. Performance Predictions

The beginning of the testing should not work well for this design or project. The numbers that are being calculated are only given through articles on the internet or known information. It will need to go through some re-design as the year progress to better suit the needs and wants through the original function statement in the introduction. But, through some testing and real-life applications the insert should bode well.

e. Description of Analyses

The analyses that this project will go through are varied. The project will need to go through various stress and strain analyses, weight calculations, and countless other force calculations throughout its initial phase of design.

f. Scope of Testing and Evaluation

g. Analyses

A1- Horizontal Impact Testing of the Base

The base plastic is ABS and the force needed to withstand through the bumper impact is around 20 N of force. This base helps guide the bumper and adds a reinforced back to the bumper to help with any contact. As seen in A1 the base went under various force and weight calculations to come up with a force of 20 N. a picture of the base can be seen in drawing B1.

<u>A2- Vertical Impact Testing on the Insert</u>

This was used to calculate how much force the whole insert could take when the insert is being dropped or "stepped" on from a two-foot height. In the A2 analysis, the calculations used are shown to give the force it can withstand to be around 107 N. This may not seem like a lot but with proper testing the insert could come out to be higher.

<u>A3- K Factor for Leg and Foot</u>

This value was calculated in order to find the "K" factor for a foot or leg. The value will be used for later calculations if need be regarding deformation in the insert material. The difficulty was trying to find the equation that worked best for a foot since the leg was all that could be found. After using an equation online, the value came out to be 71.3 as seen in A3.

<u>A4- Weight of the base</u>

The whole insert needs to be accounted for being lightweight, so it does not weigh down the foot or person wearing it. In A4 below, the equations shown calculated the mass of the base part of the insert through means of simple volume and density equations. The base was calculated to be around .295 pounds which is exactly what the weight needed to be for just the base.

<u>A5- Weight of the bumper</u>

Just as previously stated the insert needs to be optimized and accounted for with the weight. In A5, the same calculation methods used in A4 to calculate the weight of the bumper were used. Through the calculation it was found that the weight of the bumper to be about .335 pounds. This makes the weight of the insert to be around half a pound which is exactly where it needs to be for the person to not feel uncomfortable.

<u>A6-Frictional Force on the inside of the insert</u>

The inside of the insert is the piece that connects the whole part to the foot. There will be a frictional force associated with the skin to the ABS plastic in this case. According to the simple calculations in A6, the frictional force on the inside of the insert is 9.8 Newtons. Which, in this case of the insert, seems pretty reasonable.

<u>A7- Endurance Limit</u>

The endurance limit shown in A7 is around where the limit was thought to be. Through the calculations shown and using an Sn of 300, the limit was fond to be 209.29 psi. Which, for a piece that goes towards the front of a foot is not that bad. This value could change as the project changes and changing the value of Sn to something closer to 400 would increase the value as well.

A8- Deflection of bumper

The front bumper of the insert is made up of a different plastic than the rest of the insert. The reason being is the n-Gen flex material is more flexible than ABS and would allow for more issues to occur. Through the calculations in A8, it was found that the front bumper could deflect just over half an inch without failure. After that, there will be mechanical and other issues associated with the piece. This seems like a good deflection for a bumper because it’s high enough not to worry about and will need a good amount of force to break past.

A9- Normal Stress

In appendix A under A9 there are calculations for the normal stress of the cylinder. Using the diameter of 4 inches and using the sample of 300 pounds the calculations were simple. Using the diameter, the area was found to be 4 *pi* or around 12.56 in squared. After finding the area it can be used to calculate the stress by dividing the sample of 300 pounds by it to get a simple normal stress of 23.87 psi.

A10- Hoop Stress

In A10 the hoop stress was calculated using the diameter of 4 inches, wall thickness of .5 inches and a 300lb force. The 300-pound force was used to fit a required size and weight for the insert. By multiplying the 300-pound force and dimeter it was found to be 1200-pound inches and was divided by 2 times the wall thickness which just happened to be 1. So, the final answer came to be 1200 psi with the equation found online.

A11- Longitudinal Stress

In A11 the longitudinal stress was found using the same given materials in A10. The equations were roughly the same except the thickness of the wall was multiplied by 4 not 2. Which makes the final answer to be 600 psi. This answer seems to fit the right requirements of the part and is used for the insert not just the one piece or other.

A12- Modulus of Elasticity

The modulus of Elasticity was found in A12 in appendix A. Using the E value of .33 x 10^6 psi which was found online and the poisons of .35 which was found online the value could be found. By simply using the equation in A12 the modulus was found to be 1.22 x 10^5 psi which sounds really high for ABS plastic. This is for the base not the bumper of the insert since the bumper is made of a different plastic.

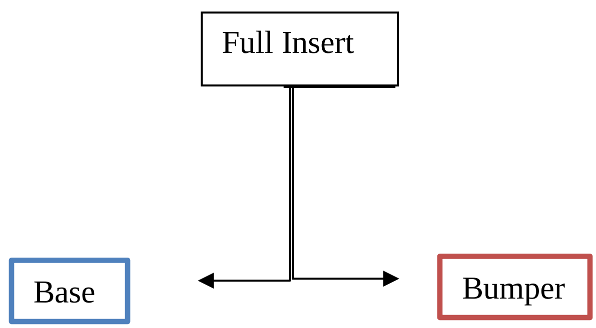
3. METHODS AND CONSTRUCTION

a. Construction

i. Description

The full insert will be made of one plastic material. There will be a bumper piece and a base piece for the insert to have. The plastics will be ABS plastic for the base piece as well as ABS plastic for the bumper. The two pieces will be connected by a screw that is glued and set into the front bumper of the pieces. The pieces will have to be 3D printed over a few hours' time and will have to be made at separate times since they are different pieces and the machine is not all that big. After that there will potentially be a sanding process to follow the 3D printing. The sanding will be used to smooth the surface and make the surface of the insert be more applicable to a coating if it was chosen to do so.

ii. Drawing Tree



b. Method

Following through the steps placed in Appendix A there will be many methods needed to find the requirements of the project. The various methods will include strength, tensile, and hardness testing. The ABS plastic has already been tested in some capacity by the professors here at Central Washington University. But the methods that they used will need to be replicated and used again for the specific material at the time of the project being printed and made. Each time a plastic is made the material will react differently to the method done at the time. The various parameters that will be needed to test will be the stresses on the material and the force and impact testing on the insert. These properties will need to be optimized because they are the critical points to follow regarding the insert since they are the most important to a given material. Not only will these tests need to be ran on the ABS base, but they will also need to be ran on the front bumper as well.

There are no real benchmarks to base the insert on and will need to follow regarding other designs. The other inserts for this issue are made of a soft felt material and are more like a custom sole for a shoe, not an actual insert. So, there is nothing to base the information on other than full leg orthopedics but there are major differences in the two so it is difficult to compare at the end.

The issues associated with the project are high, ABS plastic can be reliable but also can change due to temperature or type of ABS that is chosen. The way to fix this is to print in a room with an even room temperature each time and print the pieces with the same ABS plastic. This should help minimize the "randomness" that could happen with the project.

c. Discussion

As stated above the project will need to be printed into two pieces over the course of a couple days. Printing on the same day would be optimal to maintain the same ambient temperature and material, however, printing takes an extended period of time so it would not seem to work out that way. By doing them in consecutive days or prints it should minimize the ability for the pieces to be too different from one another. 3D printing would be the simplest way to produce the project and also use it for molds in the future if need be. The 3D printing was by far the best method and actually being able to print on consecutive days was able to be done. This was able to be done because the pieces were printed to only have a 15-20 percent fill. This was because it was known ahead of time that the pieces would need to be edited and re-printed for the remainder of the year.

The testing method used for the first test was initially meant to be a charpy test for impact. However, the charpy tester was too small for the designed piece so a slide and hammer were used instead. The hammer weighed ten pounds and the slide was eighteen inches long. The ten-pound weight was then dropped down the slide to impact the top of the insert. The impact test showed to give an impact of 98 pounds of force. This test was to show the effect of force on the front of the insert like a person kicking a door or wall. There was originally a requirement of 20 pounds of force, so the impact test was five times as much. The insert did not break either so there is room to grow for the impact of the piece. This held true for the other design changes and showed that the piece was solid for the impact testing.

The second test was a fit test done in the shoe for the individual the insert is being designed for. The test as used to see how much the insert could fit into the shoe as well as how much the shoe stretched upon insertion. The design used for the insert for the fit test was a failure. The insert did not fill out the front of the shoe completely and the base of the insert stretched the shoe too wide. The original requirements are to have the shoe be filled out and the insert to not stretch the width of the shoe past its desired maximum width. Moving forward there will be a re-design or two of the insert to ensure it fills out the requirements that it has been given. There was about 4 total re-designs that were made. The reason being is because the pieces had to be tweaked and changed for very small differences. The parts were then printed and then tested the next weekend. This test was the most important test for the success of the project simply because it is the sole purpose of this project. If the project didn’t fit within the shoe, then there was no point to the project.

The third test was the hardness test. The requirement for this was for the piece to withstand a hardness of 100 pounds per square inch. The location of this piece was where the insert overlapped the foot of the individual. The reason being for this location is that it is irrelevant for any other location to hold a hardness that high. The test required multiple trials and would go until any fractures or deflections started to occur. This was also tested on the insert at about a 20 percent fill on the piece. So, the result from this test was technically a failure but also showed that with a higher fill the piece would succeed. The test showed the insert could withstand a hardness of 90 pounds per square inch. Which is technically a failure but it is close enough to be considered a success. The reason the consideration for success is because with a 20 percent fill the part is barely filled. The hardness test was great for showing the strength of the piece as well as showing how even a small percentage fill can cause a piece to still succeed.

These tests showed the project to come together and become a success in the end. The final result was overall a win and the user it was built for enjoys using the product for what it was meant to be used for. Which is small amounts of time walking and doing small tasks like going to the grocery store and what not. Having all of the tests finish strong and eventually turnout was a test in itself but was also very rewarding to see them be complete.

4. TESTING

a. Testing overall

As stated above in the methods, the testing will require a vast majority of standard testing of materials. The needed testing will be impact, stress, hardness, and weight. These tests can all be found in the lab and can be used like the metal materials but will need to be run using ABS plastics. The simplest test being to weigh the insert overall to see if it matches the weight calculated. These tests will take a few runs so there will need to be multiple tries with a part. Or, there will need to be general material tests to save on the cost of materials over a longer period. A general test will be easier to manage but may not produce tangible results since it is not the exact right size of the inset. These decisions will be made prior to class in the winter for testing and will need to be further discussed with the professors to be determined what is the best action moving forward. The testing will require multiple pieces as the part will need to be stressed to the point of breaking. Both the bumper and base will need to be tested with each method used as well as the entire component will need to be tested using the previously stated testing methods.

The first test completed was the modified charpy test. The test was run using a pole and a ten-pound hammer to slam on top of the insert. There was a piece of plastic used to represent the foot of the wearer to go into the insert. This was used to manipulate the same idea as a charpy test. The only reason a charpy test could not be ran was because the insert was to big to fit into the slide and the amount of work needed to adjust the test to fit the needs of the insert was too high. So, the ten-pound hammer test was the best option for the idea of impact. Using the ten-pound hammer traveling eighteen inches, it was calculated to withstand around 98 pounds of force. This is about five times higher than originally thought as well as five times higher than needed. The original amount was twenty pounds of forces and this test reached almost one hundred. Now, there are some differences, the forces using an actual charpy test are much different than those of the makeshift model. However, the idea of impact is still used for this test and what the initial plan was intended for. The plan is to try and add weight to the pole moving forward to see how much force is needed to break the insert. That way the wearer knows how safe they are with the insert in their shoe.

The second test that was completed was a fit test. The main requirement for the insert is that it needs to fit into the shoe for the wearer. If the insert does not fit, then the insert would be a failure. The test requires the shoe of the individual and the insert. The fit test showed that the current design of the insert is a failure and does not fit into the shoe of the individual it is for. The shape is too thick and too tall. The front bumper of the insert is also too round and made the front end of the shoe stick out too far. The base of the insert is way too large in almost all spot except the width. Looking forward, there needs to be many modifications made. The overall shape of the insert needs to be changed to better slide in and out of the shoe and to make it look seamless. The first insert was too bulky and showed to be too big. The first design was just based of simple measurements and no real definite design idea. But, now that there are better measurements and a better look, there is potential for better designs going forward. There will need to be many design changes until the fit is perfect and comfortable for the wearer.

5. BUDGET/SCHEDULE/ PROJECT MANAGEMENT

a. Proposed Budget

According to Appendix- D, where there is a value of a proposed budget using an excel sheet, the budget will be $4.50. Now, this is just using the values of N-gen flex plastic and ABS plastic for 3D printing. It is also on the assumption of the time associated with the 3D printer on campus. 3D printing is not a quick process and the assumption is that each will only take a few hours to complete. These numbers are subject to change as information about the length of time the 3D printer takes as well as the size and shape of the insert changes with revisions. As well as $4.50 seems low for a 3D printer especially with the multiple parts the insert needs. There could be a doubled or tripled amount for how many copies the project will need for testing. The tests require some breaking so there will need to be more than one copy of the insert.

The most recent idea to come about was to buy a $20 spool of 3D printing material to use for many prints of the insert. This will cut the cost into a fraction of the amount and will allow for multiple prints without the penalty of expense. By buying the one-time cost of $20 it will take the printing cost away because the department does not add extra costs if the printing is done with someone’s own material. There have been multiple prints and each of them would have cost somewhere between 6-7 dollars. That being said, that makes the spool already more viable for cost. The spool was the best idea in the long run for the entire project. It made re-designs simple and efficient to make and duplicate. If not for the spool, the project would’ve cost around five dollars per print which would have gone way over budget and way higher than needed.

b. Proposed schedule

This project begins in September with the initial design and analysis of the connecter and bumper pieces of the insert. The design will come from measurements taken off of a generic foot size found online. The design and analysis portion of the project should be done by the beginning of December when finals week is done. As the winter quarter rolls in the project will be going through its initial testing, whether it be impact or stress. After the testing there will be an initial phase of re-design if the testing did not go well. The full planned schedule will be under appendix E where the Gant chart for the entire year is located. The Gant chart is a fluid document and is subject to change as the project does. The project itself will probably take close to 50 hours or so to complete, there will many hours spent testing and printing the project. There will most likely have to be multiple copies of the piece, so it will have to be many hours just sitting waiting on prints.

The testing proved the schedule to be right. The first test was right on task and showed a success and made the piece on schedule. The fit test originally was a failure and required more time to complete. The test itself was on schedule but it caused more work needed to be done so it has gone through three designs. The third design is the most efficient and closest to the right fit for the shoe it is being tested for. The schedule has been on track so far and was accounting for mistake in the original design. So, the schedule has been on track with the re-designs and modifications that have been made.

The schedule has remained on track and continued to follow the Gant chart as far as it can be. The Gant chart was simple because the project itself was not that complicated. The chart being simple made following the schedule easy and stress-free for the year. The schedule had some hiccups when there were testing issues and trying to account for multiple prints. But, those were thought of with enough time ahead in order to make sure those would not get the plan off schedule by a huge margin. The multiple prints only caused a day or two of the schedule to be changed and be off from the original.

6. CONCLUSION

For this project to be considered a success there will need to be specific requirements that will need to be met. The first one being, does the insert fit into a shoe and onto an individual. This can be achieved using a model found online or through means of a person willing to let the piece be fit to them. The second criteria for success are if it fills the weight requirement. The insert cannot be heavy since it is put into a shoe of an individual. A heavy insert will ruin the integrity of the shoe overtime and be costlier then cost effective if that happens. The final requirement will be if the insert can withstand the forces being acted upon it. The forces of everyday life will eventually wear down the insert and if the insert breaks down while on an individual in a shoe it could cause serious damage with breaking and shards. These requirements being met will make the project a success.

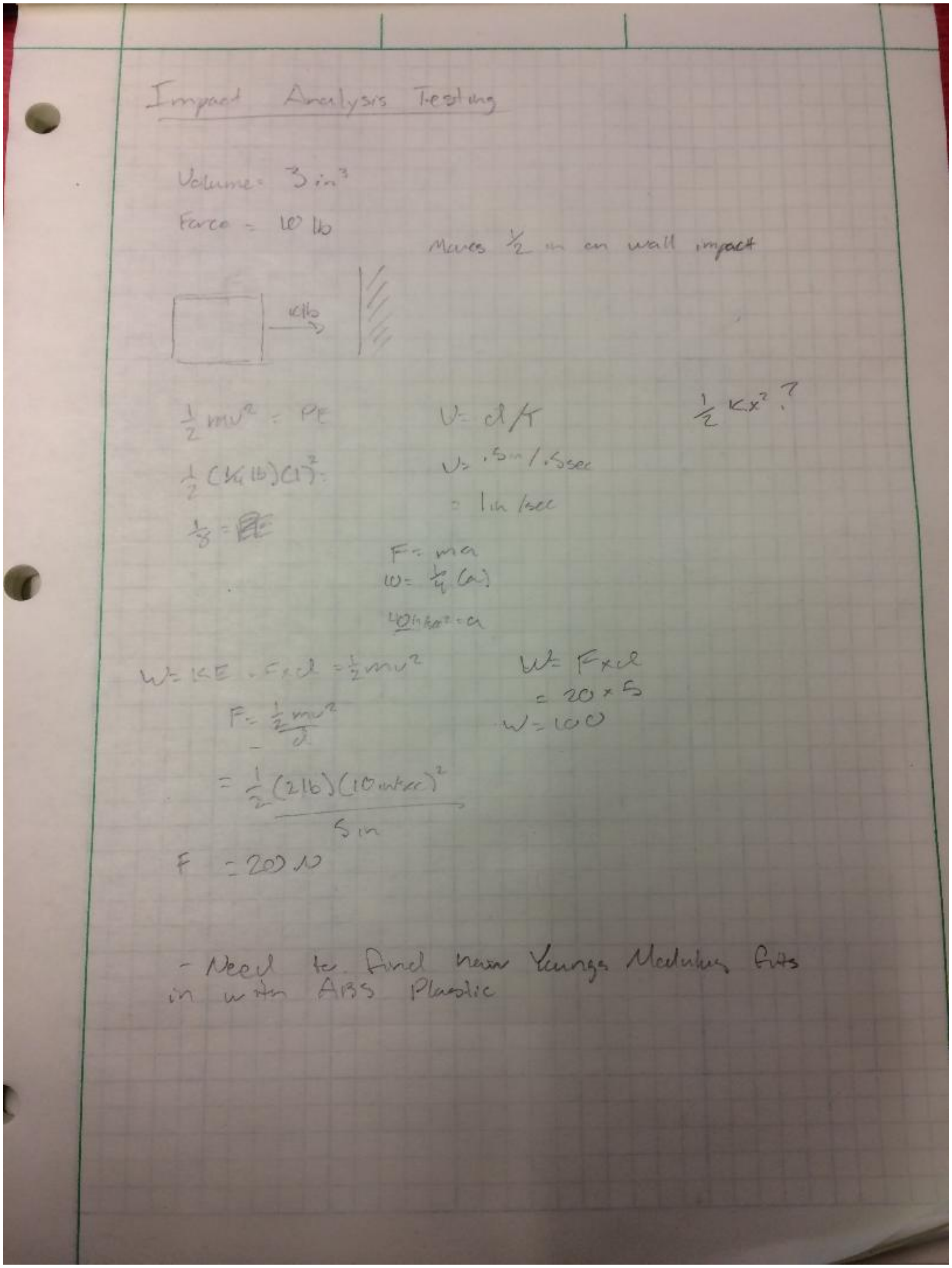
The project did meet all of the requirements and overall was a success. This was more difficult than previously thought. The idea of having to print several copies of a piece was a surprise. It was originally thought that the project would be done within a second printing and that was a very naïve idea. But, nonetheless the project is finished and completed with the idea of it being an overall success. The amount of time used on the project was worth having the project be a success and having the person it is meant for using it on a regular basis. As well as the person it is for uses the project over their actual expensive prosthetic for most tasks. The other prosthetic is used for longer excursions but for simple tasks, the insert that was made was perfect for those small tasks.

7. ACKNOWLEDGMENTS

Many thanks to the staff at CWU for the continued support throughout this process and the help there will need to be. The project will be worked on with Professor Pringle and Doctor Johnson more than any other people on this project. There will be plenty of help building this project and Pringle will be able to help the project get 3D printed out and what is needed with that process. Johnson is the materials man and any testing help will need to go through him to be approved by him.

Appendix A

This is a base analysis for the impact of the prosthetic. The challenge is trying to find how ABS plastic works as a sort of spring. These numbers are arbitrary and are meant to be stepping stones for calculation purposes.


Impact Analysis Testing

Volume = 3 in^3

Force = 10 lb

Moves $\frac{1}{2}$ in on wall impact

10lb

$\frac{1}{2} mv^2 = PE$

$\frac{1}{2}(\frac{1}{4} \text{ lb})(1)^2 =$

$\frac{1}{8} =$

$v = d/t$

$v = .5 \text{ in} / .5 \text{ sec}$

$= 1 \text{ in/sec}$

$\frac{1}{2} kx^2$?

$F = ma$

$w = \frac{1}{4}(a)$

$40 \text{ in/sec}^2 = a$

$W = KE \cdot F \times d = \frac{1}{2} mv^2$

$F = \frac{\frac{1}{2} mv^2}{d}$

$= \frac{\frac{1}{2}(2 \text{ lb})(10 \text{ in/sec})^2}{5 \text{ in}}$

$F = 200$ N

$W = F \times d$

$= 20 \times 5$

$W = 100$

- Need to find how Youngs Modulus fits in with ABS Plastic

A2- Vertical Impact force on the insert

Vertical impact force

$W = PE$

is $F \times d = m \times g \times h$

$1\,lb = .454\,kg$

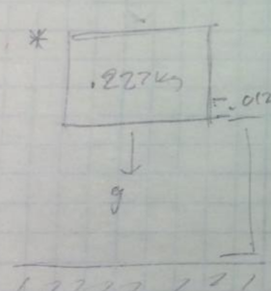
$F = \frac{mgh}{d}$

$2ft = .61m$

$$F = \frac{(.227kg)(9.8m/s^2)(.61)}{(.0127m)}$$

$= \approx \boxed{107N \text{ of Force down}}$

*



* insert will not be a square but I am using a square as an easy drawing to show work

A3- The K factor for calculating the amount of movement it will have due to a force

Chandler Stranti | MET 452 | October 19, 2018

Given: $F = 107\,N$
$\Delta L = 2\,ft$

Find: Kleg / Kfoot

Method: 1) Kleg equation

Solution:

$$K_{leg} = \frac{F}{\Delta L} = \frac{107}{2ft} = \boxed{53.5}$$

This is the constant for an entire leg

for a foot it would be closer to

$$K_{foot} = \frac{F}{\Delta h} = \frac{107}{1.5ft} = \boxed{71.3}$$

This represents the constant from the top

vert the front of the insert

A4- Weight of the base

Chandler Strenli | MET 489 | October, 14, 2018

Given: - Density of ABS ~ .0376 #/in^3
- Height of 2.5"
- Diameter of 2"

Find: Minimum mass and weight

Method: 1) Volume formula
2) Mass formula
3) weight formula

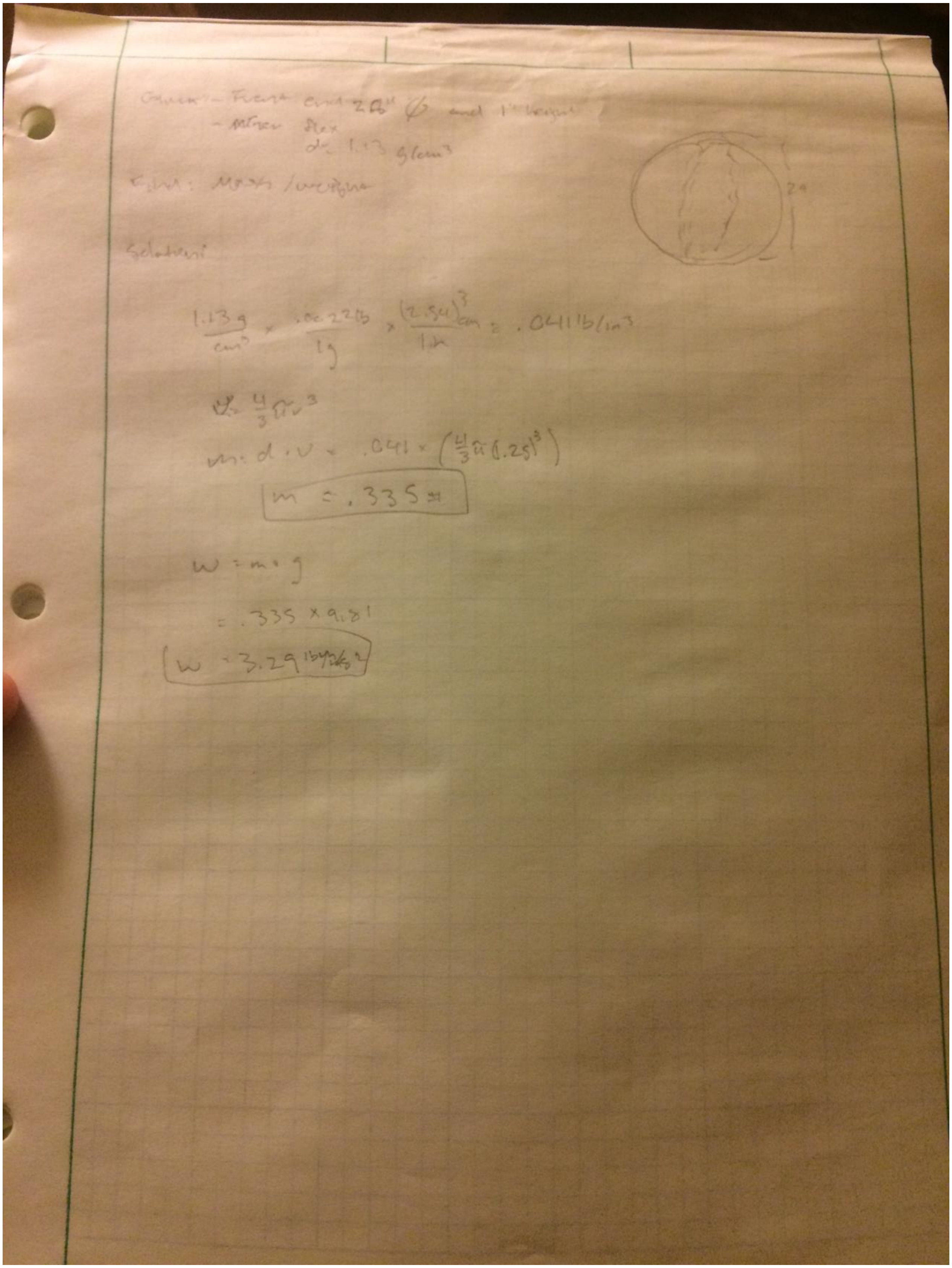
Solution:

$$V = \pi r^2 h$$
$$= \pi (1)^2 (2.5)$$
$$= 7.85 \text{ in}^3$$

$$M = d \cdot V$$
$$= (.0376)(7.85)$$
$$= \boxed{.295 \,\#}$$

$$W = m \cdot g$$
$$= (.295)(9.81)$$
$$= \boxed{2.89 \,\# \text{ft/s}^2}$$

A5- Weight of just the Bumper piece



Given: - Front end 2.5" ϕ and 1" height
- Mirror flex
$d = 1.13\ g/cm^3$

Find: Mass / weight

Solution:

$$\frac{1.13\ g}{cm^3} \times \frac{.0022\ lb}{1\ g} \times \frac{(2.54)^3\ cm}{1\ in} = .041\ lb/in^3$$

$$V = \frac{4}{3}\pi r^3$$

$$m = d \cdot V = .041 \times \left(\frac{4}{3}\pi (1.25)^3\right)$$

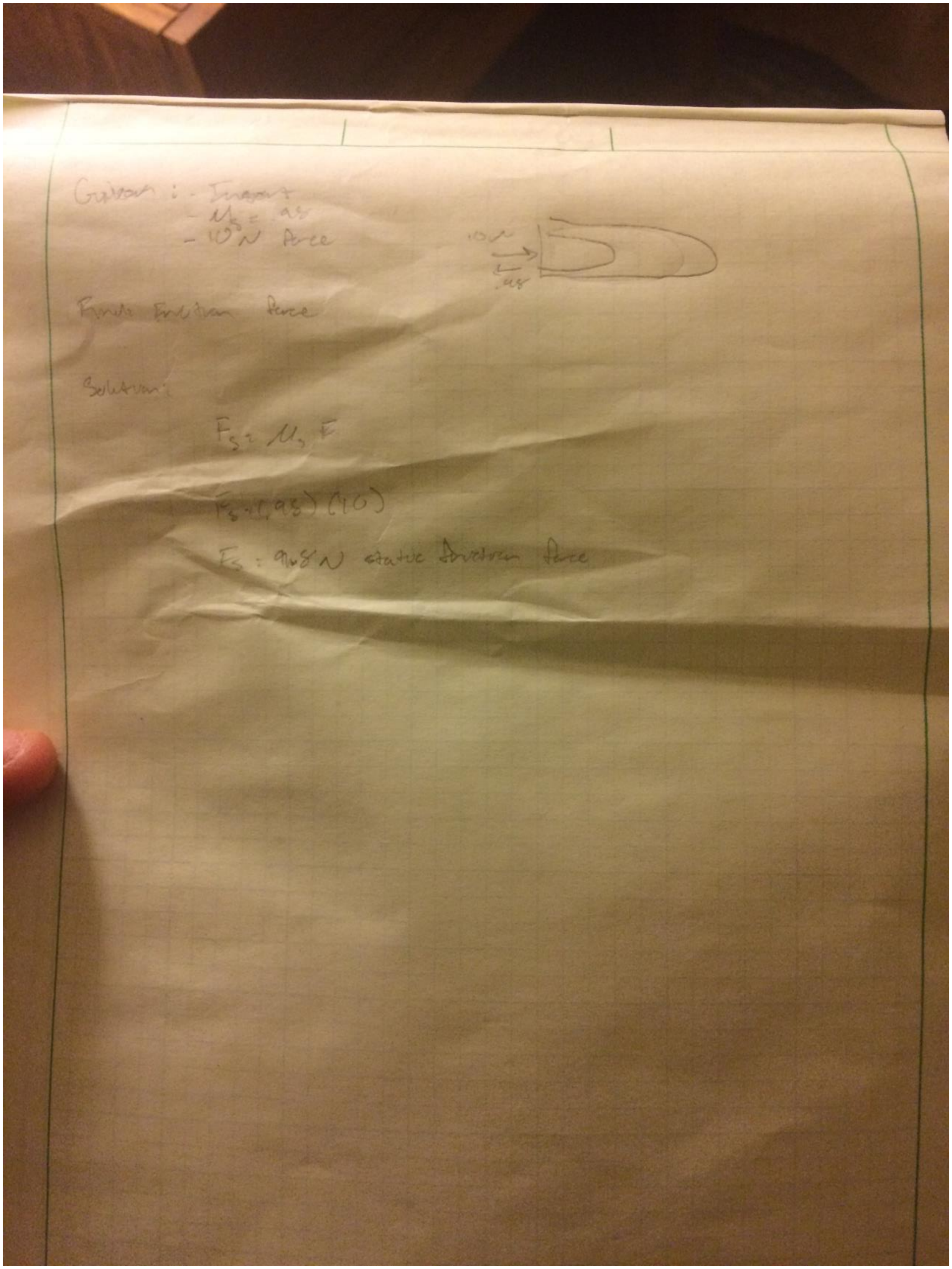
$$\boxed{m = .335\ lb}$$

$$w = m \cdot g$$

$$= .335 \times 9.81$$

$$\boxed{w = 3.29\ lb\cdot m/s^2}$$

A6- Frictional force on the inside of the insert



Given: - Insert

- μ_s = .98

- 10 N Force

10 N

.98

Find: Friction force

Solution:

$F_s = \mu_s F$

$F_s = (.98)(10)$

$F_s = 9.8 N$ static friction force

A7- Endurance Limit

Chanelle Stroud | MET 489

Endurance Limit

$S'_n = S_n (C_m)(C_{st})(C_R)(C_s)$

$C_m = 1.00$ $S_n = 300$

$C_{st} = 1.0$ (Bending)

$C_R = .90$

$C_s = .775$

$S'_n = (300)(1.00)(1.0)(.90)(.775)$

$\boxed{S'_n = 209.25 \text{ psi}}$

A8- Deflection of Bumper

Chandler Straub | MET 439

Horizontal Impact of Bumper by walking

$E = \frac{1}{2} m v^2$

$W = \frac{1}{2} F_{max} S$

$= \frac{1}{2} k S^2$

$\frac{1}{2} F_{max} S = \frac{1}{2} m v^2$

$F_{max} = m v^2 / S$

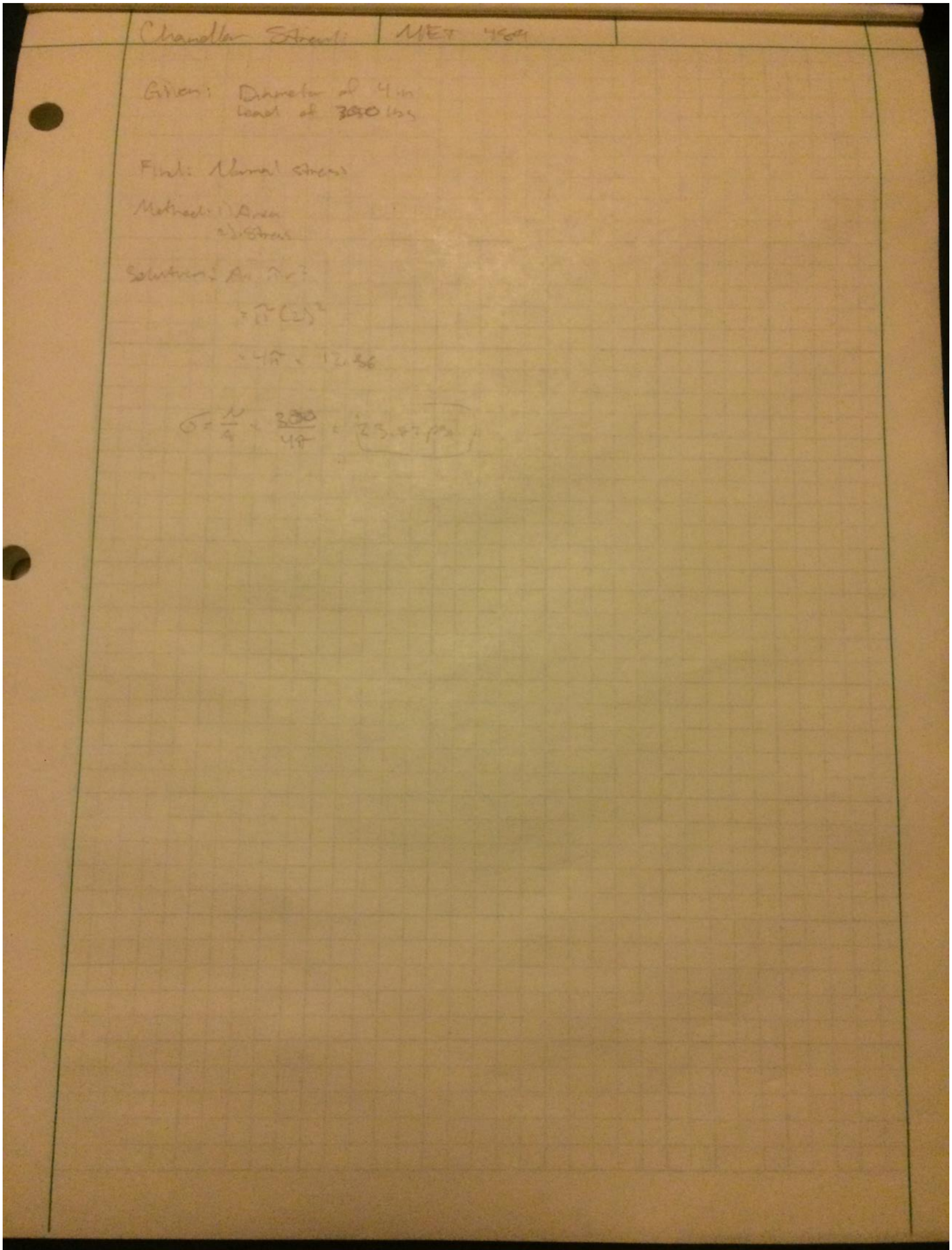
$S = m v^2 / F_{max}$

S = deformation

$S = (.335\#)(6\ in/s)^2 / 200\ lbf$

$\boxed{S = .003\ in\ \text{deflection}}$

A9- Normal Stress



Chandler Stranti | MET 464

Given: Diameter of 4 in
Load of 300 lbs

Find: Normal stress

Method: 1) Area
2) Stress

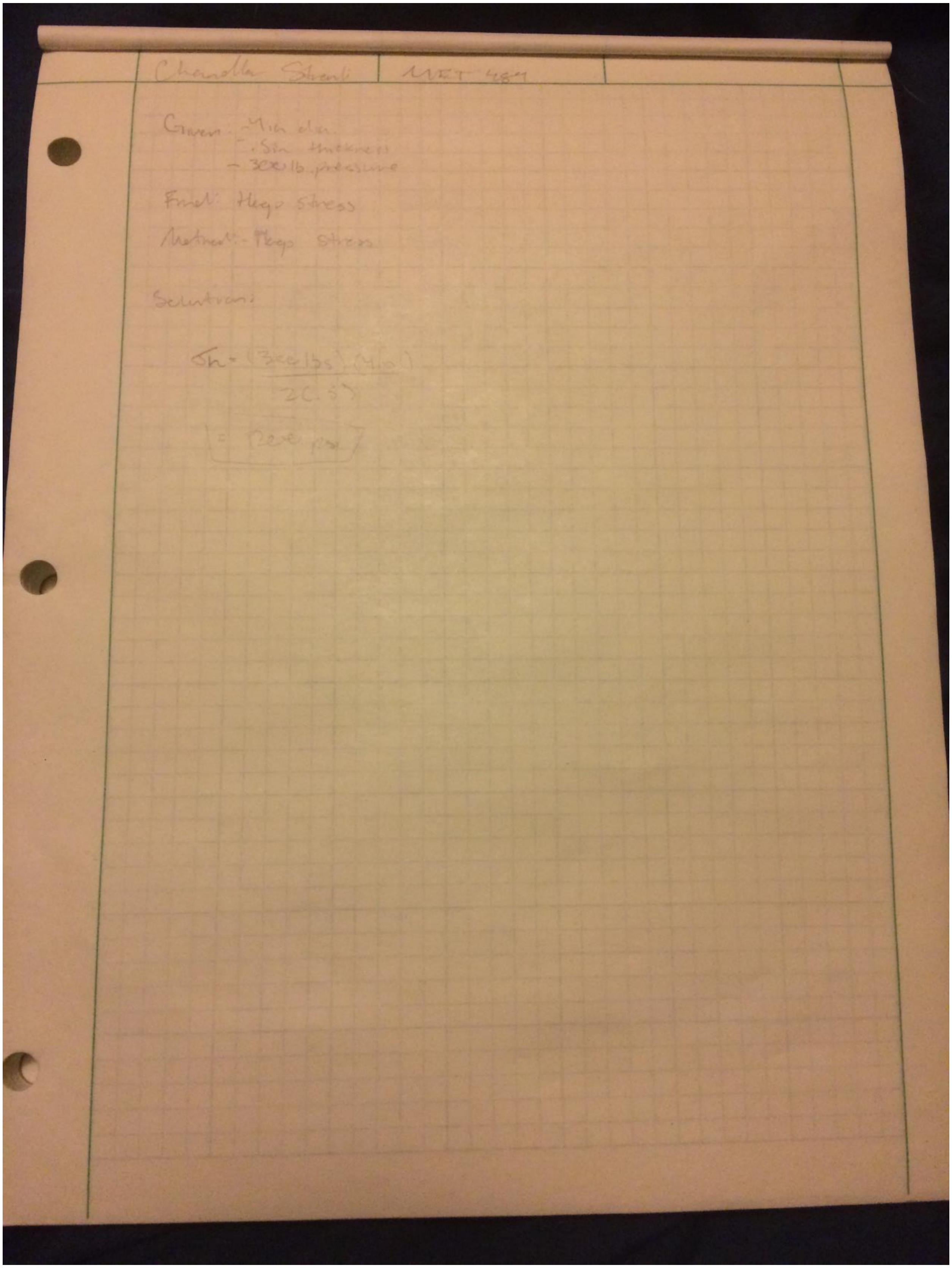
Solution: $A = \pi r^2$

$= \pi (2)^2$

$= 4\pi = 12.56$

$\sigma = \frac{N}{A} = \frac{300}{4\pi} = \boxed{23.87 \text{ psi}}$

A10- Hoop Stress



Chandler Strachi | MET 484

Given: - 4 in dia.
- .5 in thickness
- 3000 lb. pressure

Find: Hoop stress

Method: - Hoop stress

Solution:

$$\sigma_h = \frac{(3000\,\text{lbs})(4\,\text{in})}{2(.5)}$$

$$\boxed{= 12000\ \text{psi}}$$

A11- Longitudinal Stress

Chancellor Street | MET 489

Given: - 4 in diameter
- .5 in thickness
- 300 lb pressure

Find: Longitudinal Stress

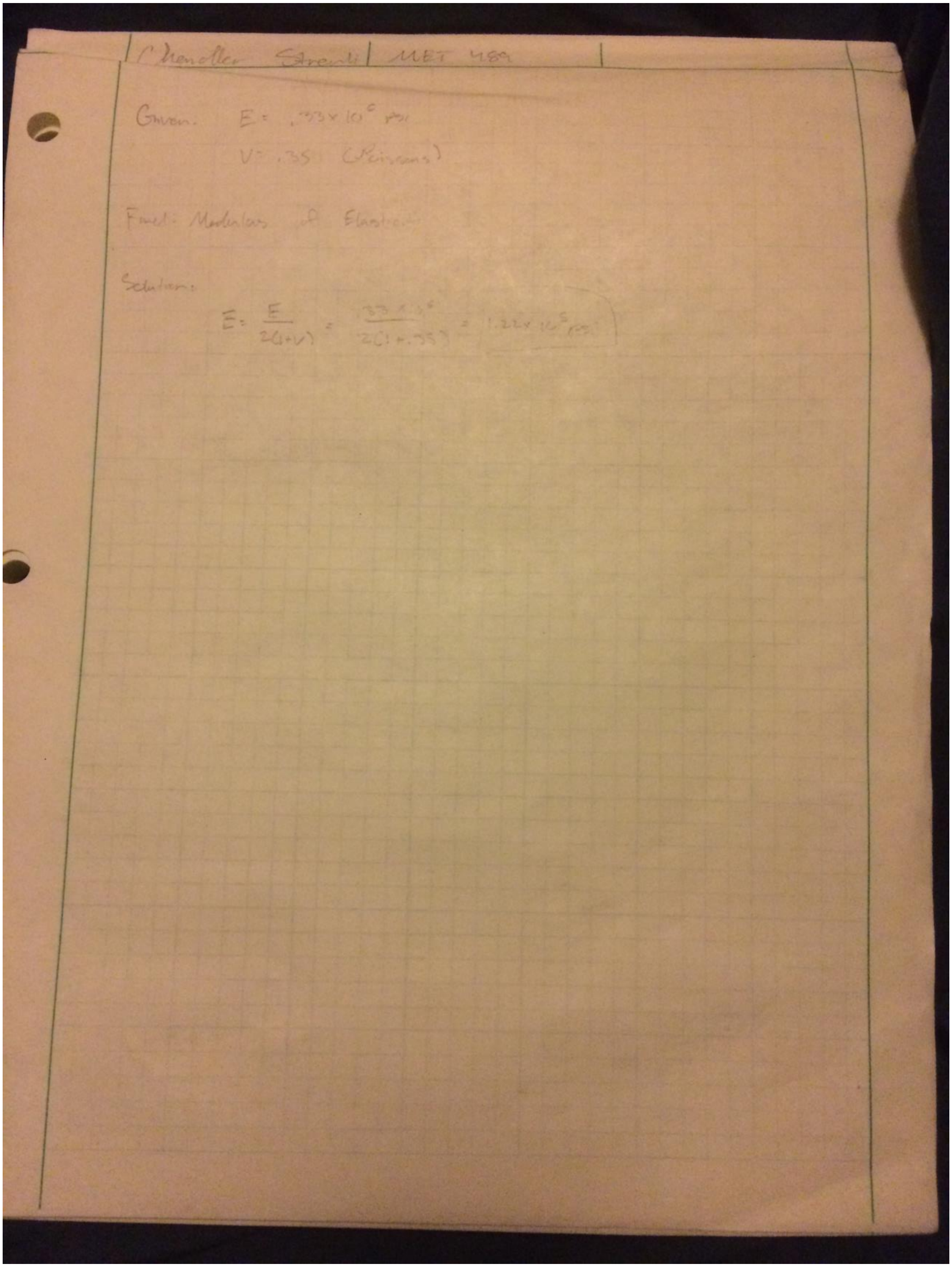
Method: Longitudinal Stress

Solution: $\sigma_L = \frac{(300\text{ lb})(4\text{ in})}{4(.5\text{ in})}$

$\sigma_L = \frac{1200}{2}$

$\boxed{\sigma_L = 600\text{ psi}}$

A12- Modulus of Elasticity



Chandler Strenli | MET 489

Given: $E = .33 \times 10^6$ psi

$V = .35$ (Poissons)

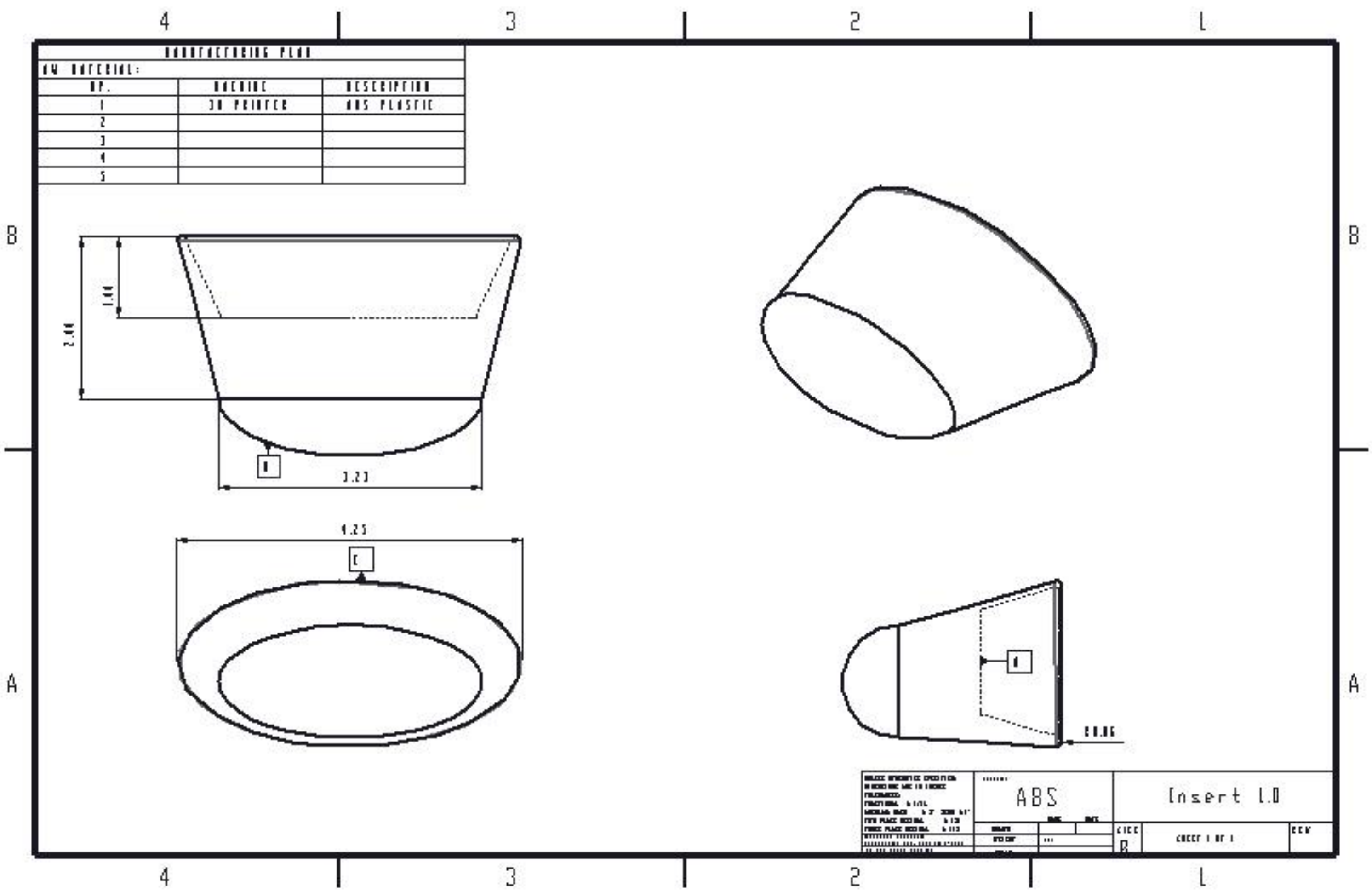
Find: Modulus of Elasticity

Solution:

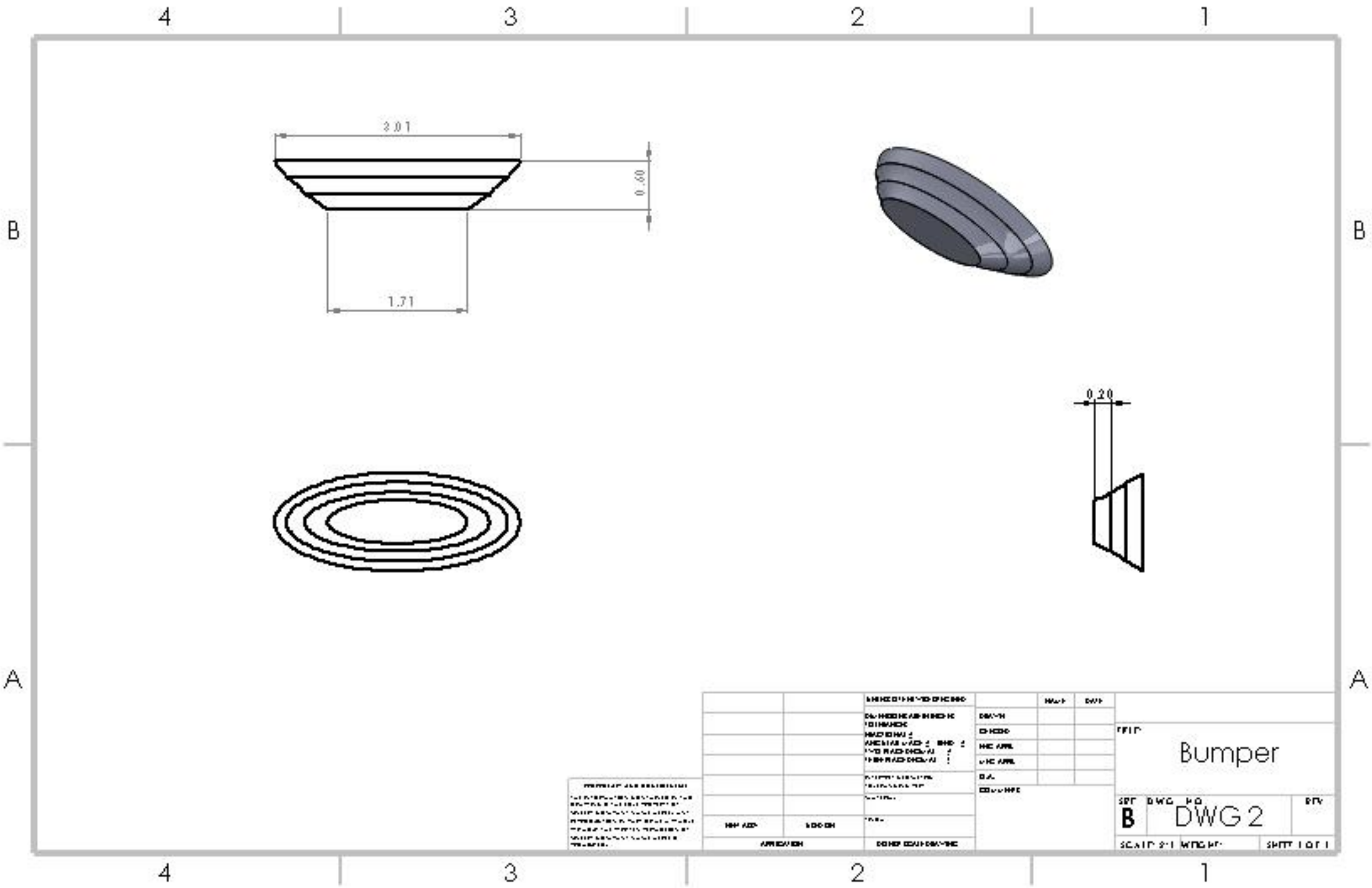
$$E = \frac{E}{2(1+v)} = \frac{.33 \times 10^6}{2(1+.35)} = \boxed{1.22 \times 10^5 \text{ psi}}$$

Appendix B

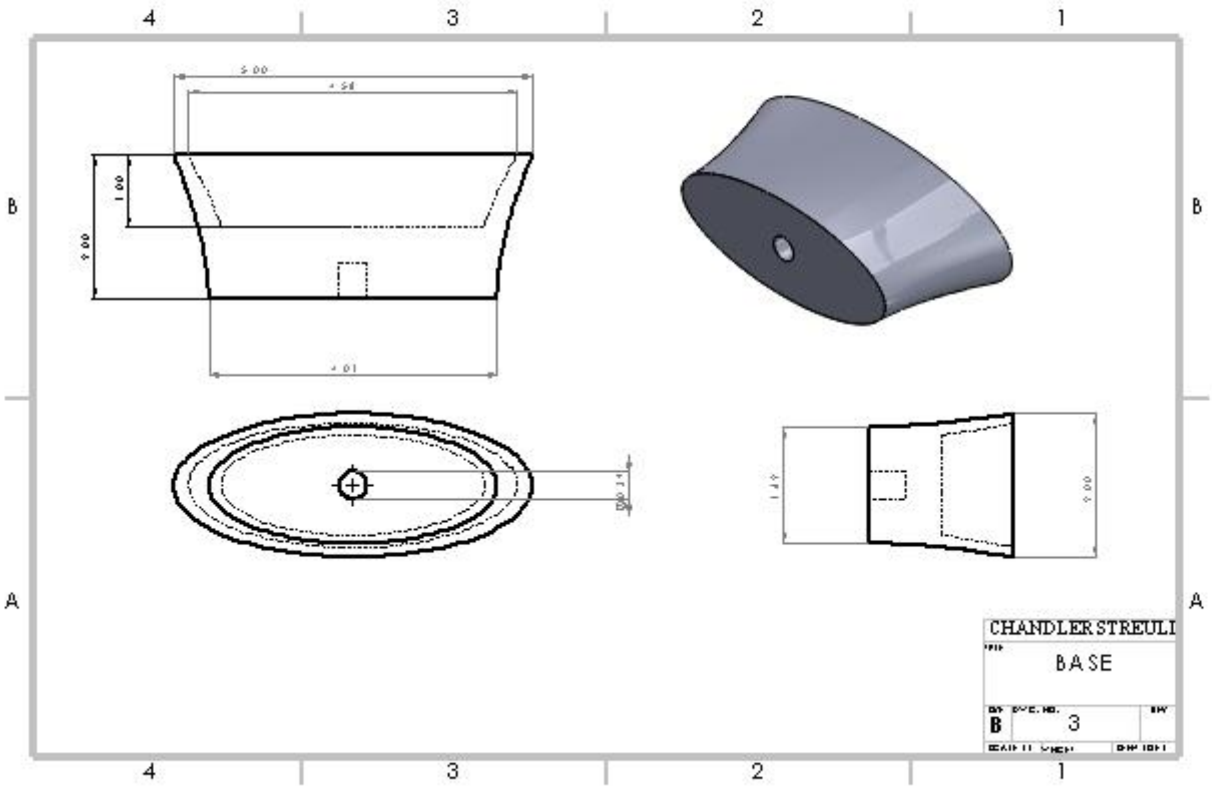
This is the first draft of the insert. Dimensions and look are subject to change over time as testing occurs.



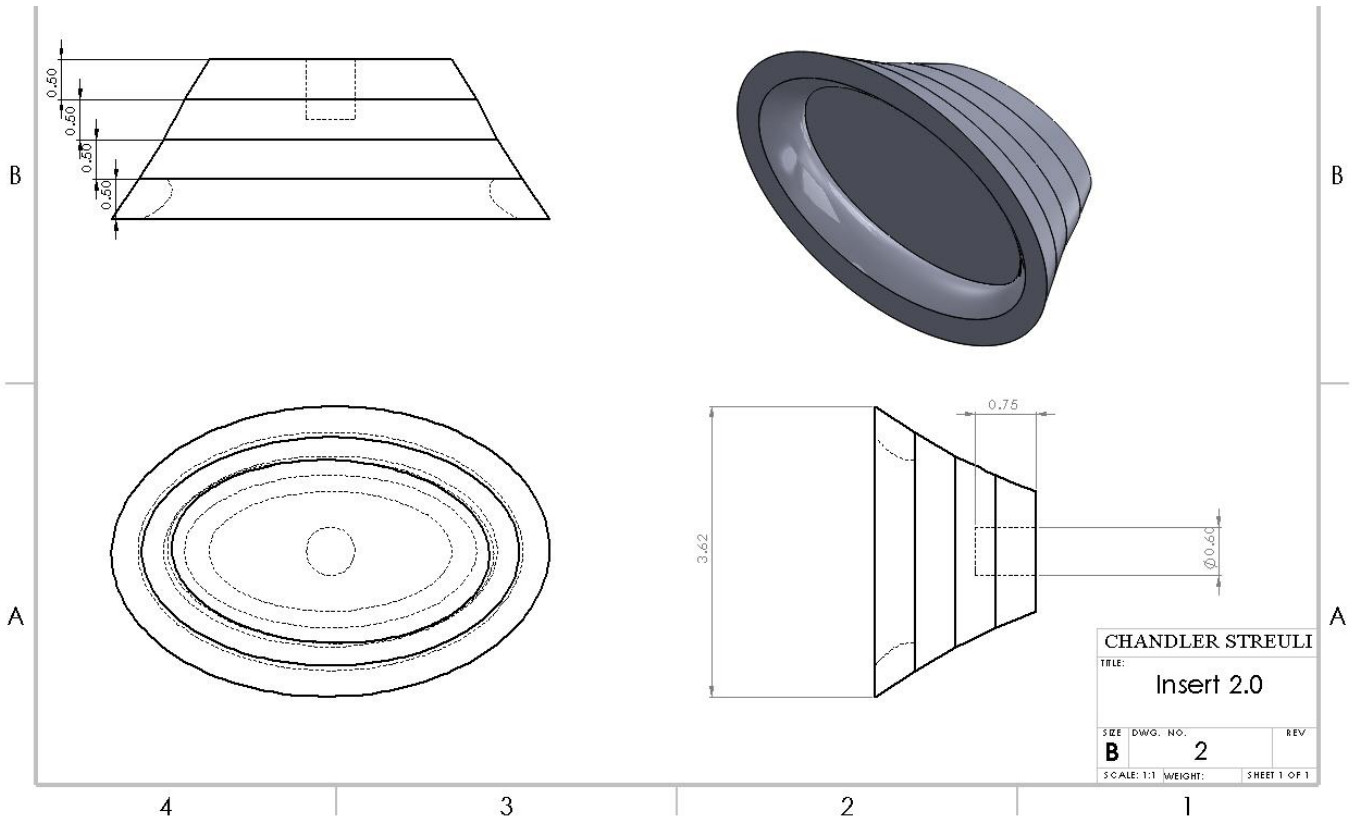
B2- Bumper of Insert



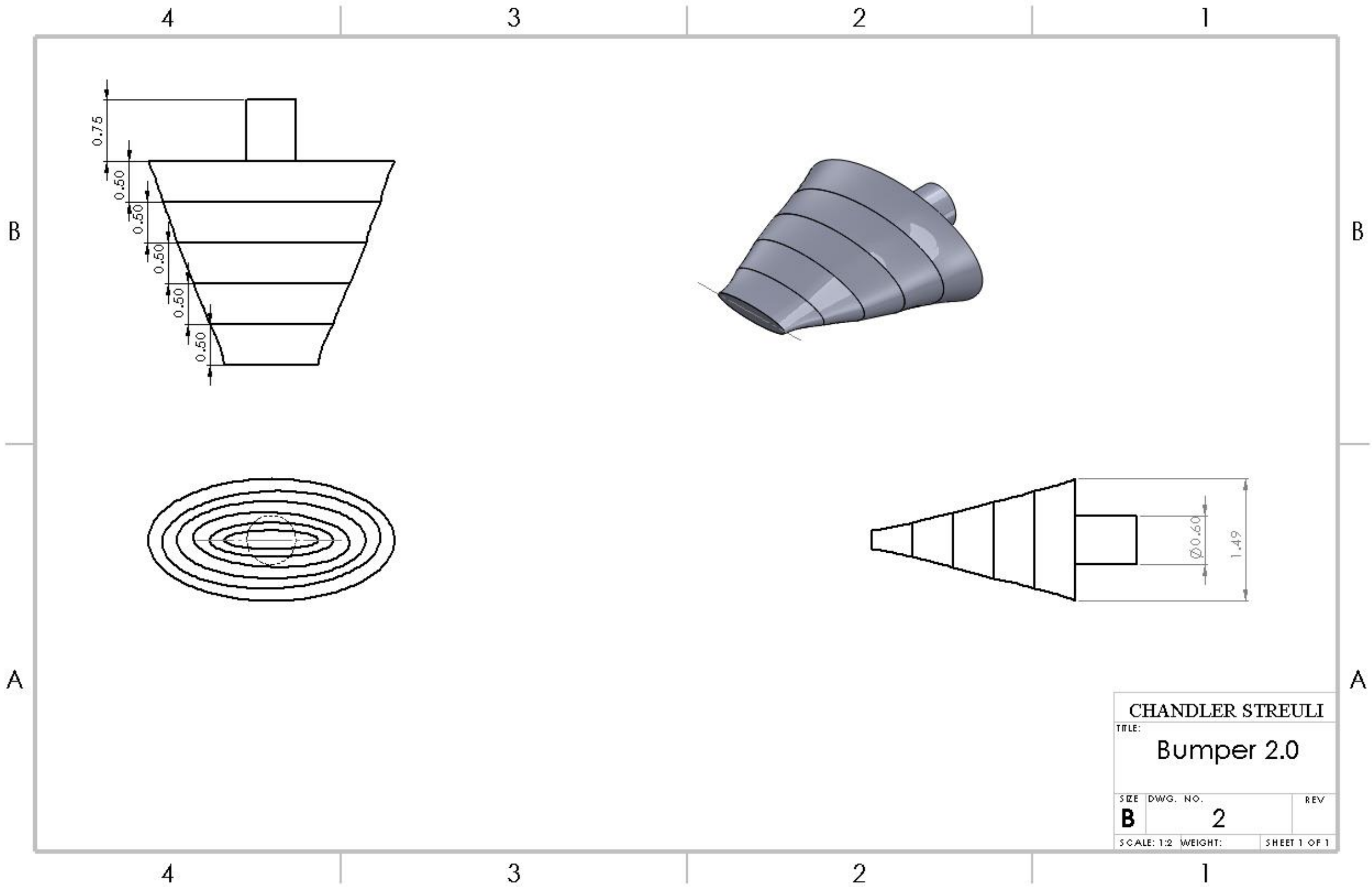
B3- Base of Insert



B4- Base 2

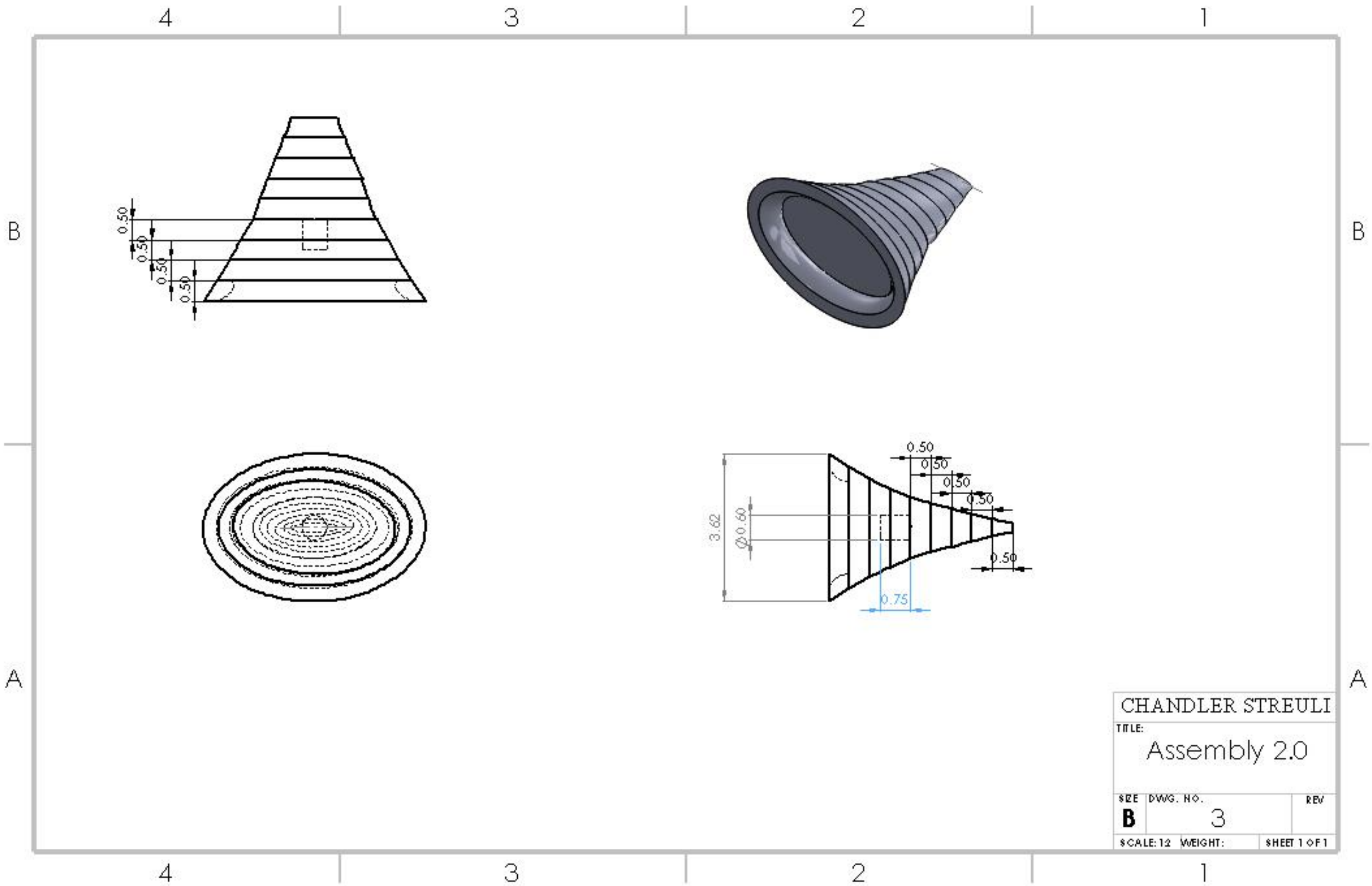

0.50
0.50
0.50
0.50
0.75
3.62
Ø0.60
CHANDLER STREULI
TITLE:
Insert 2.0
SIZE
DWG. NO.
REV
B
2
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1

B5- Bumper 2



4
3
2
1
B
A
0.75
0.50
0.50
0.50
0.50
0.50
Ø0.60
1.49
CHANDLER STREULI
TITLE:
Bumper 2.0
SIZE
DWG. NO.
REV
B
2
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

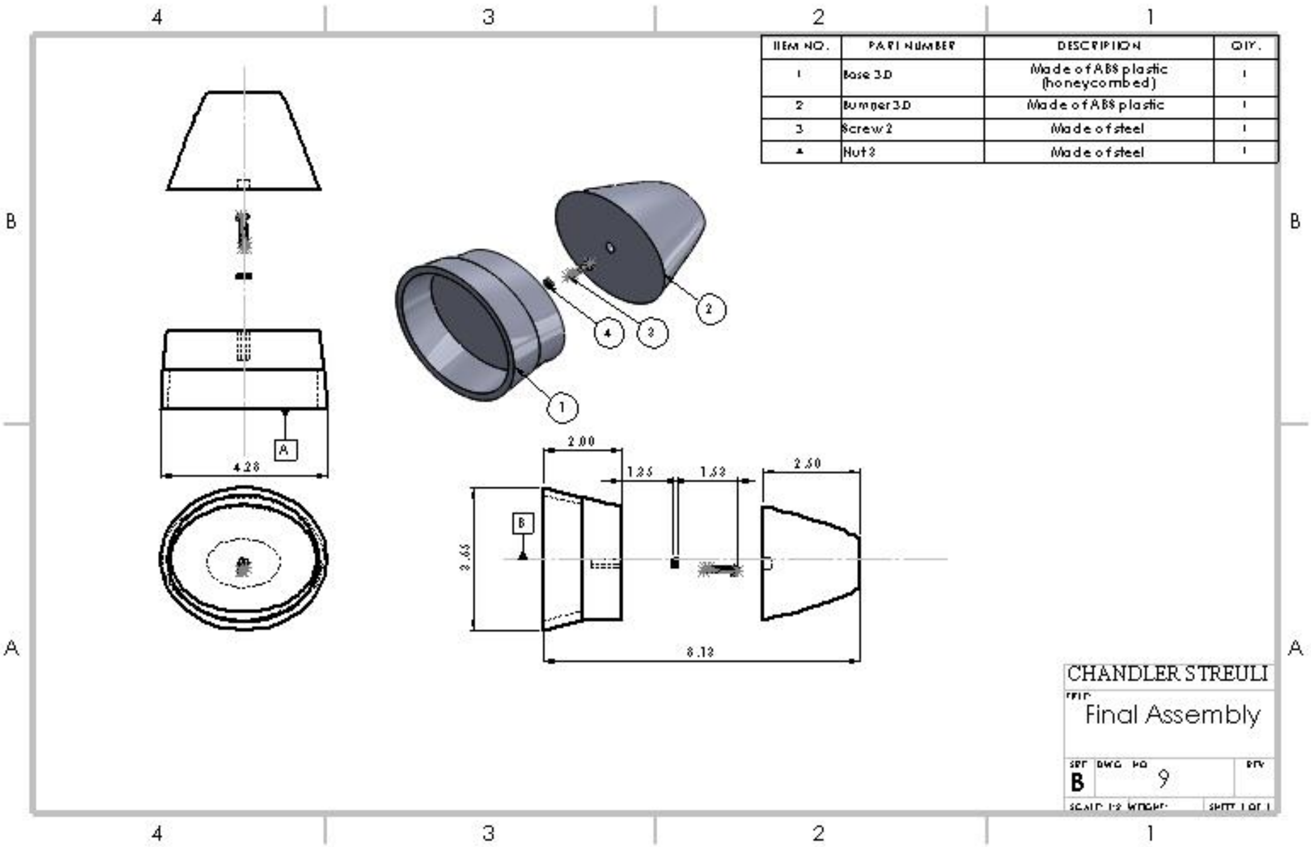
B6- Assembly 2



B7- FINAL BASE DRAWING

OP	MACHINE	DESCRIPTION
1	3D PRINTER	DESIGN STL AND PRINT
2		

B8- FINAL ASSEMBLY



Appendix D- Price List

Here is a supplemental list of prices for the various pieces involved within the project so far. They are subject to change as time progresses.

Item ID	Item Description	Item Source	Brand Info	Model/SN	Price/Cost ($/hour)	Quantity (hrs)	Subtotal	Actual Total
1	Middle Insert	CWU	PLA		$0.50/hr	3	$1.50	
2	Toe Piece	CWU	nGen Flex		$1.50/hr	2	$3	
							$4.50	

Appendix E- Schedule

Here is the tentative schedule for the project as a whole. This will change as the time and actual hours of the project go forward.

Note: March x Finals
Note: June x Presentation
Note: June y-z Spr Finals

PROJECT TITLE: INSERT FOR DIABETICS
Principal Investigator.: CHANDLER STREULI

TASK: ID	Description	Duration Est. (hrs)	Actua (hrs)	%Comp.	Sep.	October	November	Dec	January	February	March	April	May	June
1	Proposal*													
1a	Outline	1	1		X									
1b	Intro	0.5	0		X									
1c	Methods	1	0											
1d	Analysis	10	0			X								
1e	Discussion	2	0			X								
1f	Parts and Budget	1	0			X								
1g	Drawings	10	0		X									
1h	Schedule	1	0			X								
1i	Summary & Appx	2	0											
	subtotal:	28.5	1											
2	Analyses													
2a	Weight- Connector	1	1			X								
2b	Force Down Anal.- Connector	1	1.5			X								
2c	Force Forward Anal.- Connector	1	1.5			X								
2d	K factor Anal.- Insert	1	0.5			X								
2e	Weight- Bumper	1	0.5			X								
2f	Frictional Force- Connector	1	1			X								
2g	Endurance Limit	1	1			X								
2h	Deflection of bumper	1	0.5			X								
2i	Normal stress	1	0.25			X								
2j	Hoop Stress	1	1.5			X								
2k	Longitudinal Stress	1	1				X							
2l	Modulus of Elasticity	1	0.5			X								
	subtotal:	12	10.8											
3	Documentation													
3a	Connector Drawing	2	2.5		X									
3b	Bumper Drawing	1	2			X								
3c	Assembly drawing	2	0			X								
3d	Base 2	1	0.5				X							
3e	Insert 2	1	0.5				X							
3f	Assembly 2	2	2				X							
3g														
3h														
3i														
3j														
3k														
3l														
3m														
	subtotal:	9	7.5											
4	Proposal Mods													
4a	Design Change	3	0				X							
4b	Analysis change	4	0				X							
4c	Design Change	2	1.5								X			
	subtotal:	9	1.5											
7	Part Construction													
7a	Manufacture Connector	4	0						X					
7b	Sand Connector	1	0						X					
7c	Manufacture Bumper	3	0						X					
7d	Sand Bumper	1	0						X					
7e		0	0											
7f		0	0											
7g		0	0											
7h		0	0											
7i		0	0											
	subtotal:	9	0											
9	Device Construct													
9a	Insert Assembly	2	0						X					
9b	Build Base	4	5						X					
9c	Build bumper	5	4						X					
9d	Assemble	2	1						X					
9e		0	0											
9f		0	0											
	subtotal:	13	10											
10	Device Evaluation													
10a	Impact Test- Vertical	2	0.5								X			
10b	Impact Test- Horizontal	2	2								X			
10c	Fit Test	1	1								X			
10d	Hardness Test	2	3									X		
10e		0	0											
10f		0	0											
10g		0	0											
10h		0	0											
10i		0	0											
10h		0	0											
	subtotal:	7	6.5											
11	495 Deliverables													
11a	Get Report Guide	1	0.5		X									
11b	Make Rep Outline	4	2		X									
11c	Write Report	20	25		X									
11d	Make Slide Outline	0	0											
11e	Create Presentation	0	0											
11f	Make CD Deliv. List	0	0											
11e	Write 495 CD parts	0	0											
11f	Update Website	0	0											
11g	Project CD*	0	0											
11h	SOURCE	3	2.5									X		
	subtotal:													
	Total Est. Hours=	90.5	39.8				=Total Actual Hrs							
Labor$	100	9050												

Note: Deliverables*
- Draft Proposal
- Analyses Mod
- Document Mods
- Final Proposal
- Part Construction
- Device Construct
- Device Evaluation
- 495 Deliverables

Appendix G- Raw data

Test 1- The test came out to show 98 pounds of force.

Test 2- This fit test was showed to have no actual data

Test 3- The part failed at the 90 pounds per square inch mark

Result	Run 1 (30 pounds)	Run 2 (50 pounds)	Run 3 (70 pounds)	Run 4 (90 pounds)
Pass	X	X	X	
Fail				X

Appendix H- Data tables

Test 3- Hardness Test

Result	Run 1 (30 pounds)	Run 2 (50 pounds)	Run 3 (70 pounds)	Run 4 (90 pounds)
Pass				
Fail				

Appendix I- Testing Report

Test Report Guide
Introduction:

- Requirements
    - Can withstand a kicking force of 20 pounds
    - Can fit within a shoe
    - Can withstand a stiffness of 50 pounds per inch
- Parameters of interest
    - The parameter of interest for requirement one is that the front bumper of the piece is not to fail and shatter while testing
    - The parameter of interest for requirement two is that it can fit within a shoe of the individual while not stretching the shoe to the point of causing wear within the shoe.
    - The parameter of interest for the third requirement is that the pieces can withstand the force without cracking or breaking upon impact.
- Predicted performance
    - The prediction for the first requirement is that it will not break within 20 pounds of force and can go much higher.
    - The prediction for the second requirement is that it will cause the shoe to stretch but will not cause wear while in use.
    - The prediction for the third requirement is that it will not break upon impact with 50 pounds and could go much higher.
- Data Acquisition
    - The data acquisition for the requirements will all be videos if possible but if not a video it will be done by photos.
- Schedule (reference Gantt chart)
    - Refer to Gant chart posted in Appendix E

Method/Approach: (describe in detail)

- Resources (hard/soft/external, people, costs)
    - Fir the first requirement it will need the impact testing device from the Construction Management department as well as a block to into the hole where a foot would go.
    - The second requirement will need to have a shoe of the individual
    - The third requirement will need a Brinell tester as well as only a piece big enough in the right plastic density for the machine to measure
- Data capture/doc/processing,
    - For all data there will be green sheets if needed as well as picture taken by phone and videos taken by phone.
- Test procedure overview,
    - For requirement one, the test will be an impact test using a device that drops a 10 pound weight form 18 inches. The charpy tester was too small for the piece and there were too many modifications needed to be made to get it to work.
    - For requirement two, the test will be a simple fit test into a shoe. The shoe will be

from the individual the insert is for. The testing will be done at home.
    - For requirement three, the test will be a brinell hardness test. The test will be composed of trials for different weights to see the maximum weight it go into and break under.
- Operational limitations
    - The operational limitations for requirement one will be that it has to be done with a specific device and that it can only hold 10 pounds. So, if it does not break there is no way to see where the breakpoint is.
    - The operational limitation for requirement two is that it has to fit within a specific shoe size that is for the specific individual.
    - The operational limitation for the third requirement is that there is only brinell hardness testers to be done on campus. There is no way to test this way at home or any other location.
- Precision and accuracy discussion
    - For requirement one the precision and accuracy must be within .25 pounds. A quarter of a pound is not too much to be around and will not make a huge difference for the sake of testing.
    - For requirement two, the precision and accuracy must be within 1/8 inch of the maximum stretching of the shoe. The shoe can only stretch so far and if the fit of the insert can be within 1/8 of that distance it will be considered a pass.
    - For requirement three, the precision and accuracy must be within .5 pounds. The goal of 50 pounds per inch is a high goal so having some leeway to that will help the piece pass along the way.
- Data storage/manipulation/analysis,
    - For the requirements all of the data storage and analysis will be done through tables and green sheets if applicable. For instance, the fit test may not need a table or green sheet but the hardness test would need both.
- Data presentation

Test Procedure: (formal procedure)

Requirement 1

- The first test for the insert will be doing an impact (Charpy) test. This is meant to act as a representation for the insert hitting a wall. The charpy test will give the closest force impact on the insert and see how far the insert will go to the point of breaking. The test will determine the max force that could be applied to the object.
- The test setup should take about 5-7 minutes and the initial runs of testing should take about 30 minutes for the trial runs.
- This test will occur in the metals lab (Hogue 127)
- PLA plastic pieces, prototype of insert, charpy tester
- Specific actions to complete the test for requirement one
    - Place front bumper prototype into the holder
    - Secure front bumper prototype
    - Lift the hammer halfway and release
    - Record data
    - Lift the hammer to the top and release

  - Record Data
  - Repeat steps 1-6 with other bumper prototype
- The risk is that if the impact is high enough, the piece could shatter. The shatter could send plastic everywhere which could get into eyes or make cuts. Proper PPE is required including pants, shirt/long sleeve, and eye wear.
- There will need to be trials for this project to get a good use of impact on the PLA insert. There may have to be modifications to fit the piece in the holder/clamp for the tester. The impact test should show the amount of impact on the piece. The goal is to get 20 pounds of force or above. That would be the right amount if you were to kick a wall while wearing a shoe.

Requirement 2

- The second test will be a simple fit test into a shoe. The insert will be placed into the shoe of the individual that the insert is being designed for. This will act as a base line to make revisions for and to show how close the original design was for a fit into a shoe.
- The test setup should take about 4-5 minutes and will take about 10 minutes to complete
- This lab will take place at home
- PLA plastic and the shoe of the individual will be needed
- Specific actions to complete the test for requirement two:
  - Place full insert into shoe
  - Measure deflection of the material
  - Take measurements of shoe for revisions
- The risk for this requirement is the tearing and ripping of the shoe
- There is no need for trials or many tests ran with this requirement. The initial test is what all that is needed is. The goal is to have the shoe not be ripped or town upon inserting the insert

Requirement 3

- The third test will be a brinell hardness test. The insert will be placed on the tester. There is also a potential for a simple piece of PLA plastic to be used instead of the whole insert. This is because the whole insert may be too large for the tester.
- The test setup should take about 8 minutes to setup and 45 minutes to complete.
- This lab will take place in Hogue room 127
- PLA plastic and the brinell tester will be needed
- Specific actions to complete the test for requirement three
  - Place piece onto tester
  - Load 20 pounds of weight for trial one
  - Release hammer to test hardness
  - Record results
  - Repeat steps 1-4 for weights of 40 pounds, 50 pounds, and higher
- The risk for this requirement is the piece breaking and causing plastic shards flying everywhere and injuring the individual
- There is a need for multiple trials to make sure the insert does not break or fracture at a lower weight. The goal is to have the insert fracture at a weight higher than or equal to 50 pounds per inch. This weight will give the individual enough protection from falling objects while walking around.

Deliverables: (describe specific parameters and other outcomes)

- Parameter values
  - For requirement one the parameter value are that the hammer weighs ten pounds and the drop height is 18 inches.
  - For requirement two the parameter values are the dimensions of a size 12.5 shoe
  - For requirement three the parameter values are that the insert needs to be at a 50% fill on the weight needs to be 50 pounds per inch.
- Calculated values
  - For requirement one the calculated values was that the device could hold a force of 98 pounds given the parameter values.
  - For requirement two the calculated value was too big for the shoe. The insert was too large based of previous measurements.
  - For requirement three the calculated value will be added later on when the test is completed.
- Success criteria values
  - Requirement one: withstand 20 pounds of force
  - Requirement two: Fit within a shoe
  - Requirement three: hold 50 pounds per inch
- Conclusion
  - The insert is so far a success. The first test was a success and the second test was a failure. However, the second test can be easily changed to fit within the parameters. The third test has not been ran at this time but it is assumed to pass given the parameters surrounding the insert.

Report Appendix:

- Data forms,
  - The data forms will be collected and added at a later date once all the testing has been completed
- Gantt chart with test day details
  - Refer to appendix E
- Procedure checklist
  - None

Appendix J- Safety Analysis

A sample analysis for a potential hazard on the job site while working on the project.

JOB HAZARD ANALYSIS
Sanding the insert

Prepared by: Chandler Streuli	Reviewed by: Approved by:

Location of Task:	Woodshop lab
Required Equipment / Training for Task:	Sander or sandpaper
Reference Materials as appropriate:	

Personal Protective Equipment (PPE) Required (Check the box for required PPE and list any additional/specific PPE to be used in “Controls” section)						
Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
☐	☒	☒	☐	☐	☐	☐
Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.						

PICTURES (if applicable)	TASK DESCRIPTION	HAZARDS	CONTROLS
	Sanding the insert to make it smooth	**Plastic particles in the air where an someone could swallow them or get them in their eyes**	**Wear mouth and eye protection that are appropriate for each spot.**

Chandler Streuli

Mechanical Engineer and Design Professional

email: streulic@cwu.edu cell: 253-486-5429

KEY SKILLS AND KNOWLEDGE AREAS:

Proficient knowledge of SolidWorks
Classic drafting and hand drawing skills
CSWA Certified (Certified SolidWorks Associate) June 2017
ACAD Certified
Computer Certifications: PowerPoint, Word, Excel
Proficient in Windows, Adobe

EDUCATION

CENTRAL WASHINGTON UNIVERSITY

SEPTEMBER 2014 - JUNE 2019 / B.S. MECHANICAL ENGINEERING AND TECHNOLIGY

Curriculum Includes: Technical writing, basic electricity, statics, fluid dynamics, applied thermodynamics, mechanical design, three-dimensional modeling, computer aided design and drafting, application of strength of materials, computer aided design and manufacturing, applied heat transfer. 10-time Dean's List Honoree, GNAC All-Conference Academic Team 3 years in a row, with a 3.7 cum. GPA.

EXPERIENCE

RADIO ENGINEER ASSISTANT

JANUARY 2017 - SEPTEMBER 2017 / KCWU-FM 88.1 THE BURG

Assisted in keeping the radio station running on a 430-watt signal while maintaining station cleanliness while working on connecting station internet lines, running electricity and speaker wires to various locations throughout the station and campus. Worked alongside station engineer in problem solving as well as organization of the public inspection files.

LOT ATTENDANT

MAY 2015- AUGUST 2015 / GAMBLIN MOTORS

Assisted in sales and cleaning of vehicles on the lot. Worked alongside the salesmen helping answer all and any questions a potential client may have. Also assisted with the salesmen and shop mechanics on multiple different tasks on a daily basis.

VOLUNTEER WORK

CENTRAL WASHINGTON UNIVERSITY CENTER FOR DIVERSITY

APRIL 2015 - PRESENT

Participate yearly with the Yakima River Clean-up planting trees, bushes, and other plants, picking up debris, trash, moved gravel, as well as working on other tasks helping keep the Yakima River and Kittitas Valley clean.

* Professional and character references available upon request.

Appendix L- References

Doctor Choi, MET Professor, Helped with calculations

Professor Pringle, MET Professor, Helped with design and calculations

Matt Burvee, Engineering Technician, Helped with testing methods